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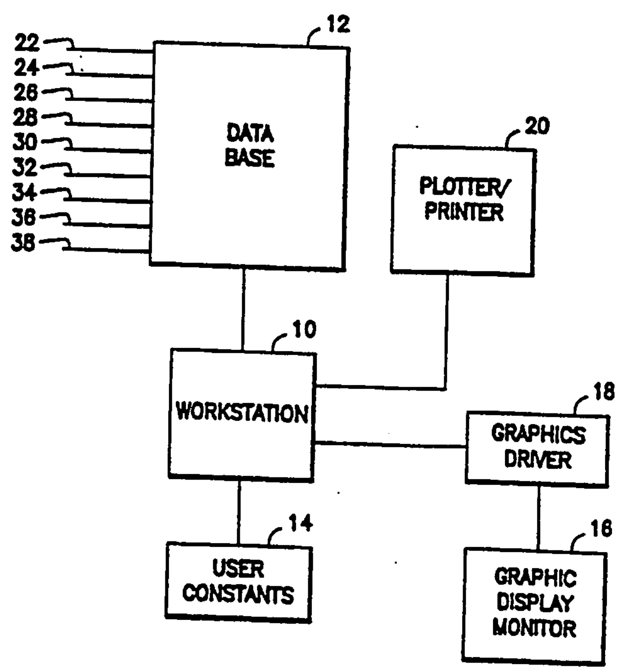
(54) Title: COMPUTER-IMPLEMENTED MODELLING SYSTEM FOR WIRELESS COMMUNICATIONS SYSTEMS

(57) Abstract

A computer-implemented modelling system integrated with a comprehensive set of software tools for wireless communications system design, management, and expansion. System simulation is provided for calculating predictive coverage areas and displaying street and topology data quickly and efficiently so that the design time is reduced and unforeseen interference effects and capacitive limitations are avoided. The computer-implemented modelling system determines the optimum placement of cell sites, how to split the cells and automatically plans the frequency allocations for the wireless communications system design. Design tools are provided for creating, storing, retrieving, editing, and calculating system specifications in an electronic data format.



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COMPUTER-IMPLEMENTED MODELLING SYSTEM FOR WIRELESS COMMUNICATIONS SYSTEMS

BACKGROUND OF THE INVENTION

1. Field Of The Invention.

The present invention relates to a computer-implemented system for the design and development of wireless communication systems. In particular, the present invention discloses a modelling system integrated with a comprehensive set of software tools for the design, development and management of cellular telephone networks.

2. Description Of Related Art.

In the design and management of cellular telephone networks, many critical decisions must be made. For example, engineers must design the network to maximize the coverage of the geographic area with the minimum number of cell sites. In addition, interference problems must be studied so that their effect is minimized. Further, the blocking probability of each cell site must be analyzed to ensure proper call initiation.

Many practical methods of designing cellular telephone networks are available to the designer. However, no system currently exists that provides all the tools needed by the designer.

SUMMARY OF THE INVENTION

To overcome the limitations in the prior art described above, and to overcome other limitations that will become apparent upon reading and understanding this specification, the present invention discloses a computer-implemented modelling system having a comprehensive set of software tools specifically developed for the design, development and management of wireless communications systems. The computer-implemented modelling system is a radio engineer's tool kit, designed to streamline development of wireless communications networks and related applications. Generally, the computer-implemented

modelling system comprises means for creating, storing, retrieving, editing, and calculating system specifications in an electronic data format, including means for calculating and displaying predicted coverage of signal strength in a system service area. Preferably, the computer-implemented modelling system is derived from models disclosed in W.C.Y. Lee, Mobile Cellular Telecommunications Systems, McGraw-Hill Book Company, 1989, incorporated by reference herein.

However, more specific features are also provided in the present invention. For example, the present invention provides computer-implemented means for determining how to plan frequency assignments for cell sites. Automated frequency assignment planning allows the engineer to optimize the assignment of frequencies to cell sites within the wireless communications system.

The present invention also provides computer-implemented means for determining how to increase the capacity of cell sites, how to split cell sites to support additional growth, and how to determine the optimum placement of cell sites. Such automated cell location planning facilitates network optimization by the engineer.

In addition, the present invention provides computer-implemented means for using digital satellite terrain data, as well as three dimensional viewing of the terrain data. Satellite data provides more accuracy than traditional topological data. Three dimensional viewing of the terrain allows the engineer to make design decisions dependant upon the viewed topology of a desired service area.

Further, the present invention provides computer-implemented means for measurement integration to refine the accuracy of the modelling system. Measurement integration allows the engineer to adjust the predicted data based on measured data collected from field sites.

The system disclosed in the present application was conceived as an integrated solution to the problem of designing wireless communications systems. Of course, one skilled in the art will appreciate that the invention is not limited to cellular telephone networks, but may be used with any wireless communications systems. Using the present invention, the development time and expense associated with the design, development, and maintenance of wireless communications system can be reduced.

DESCRIPTION OF THE DRAWINGS

Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

Figure 1 is a diagram depicting the hardware architecture of the preferred embodiment in accordance with the principles of the present invention;

Figure 2 is a diagram depicting the preferred components of the computer-implemented modelling system in accordance with the present invention;

Figure 3 illustrates the hierarchy of the computer-implemented modelling system;

Figure 4 is a flow chart illustrating the entry and verification of the digital satellite data into the computer-implemented modelling system;

Figure 5 is a flow chart illustrating the three dimensional display capability of the computer-implemented modelling system;

Figure 6 is a flow chart illustrating how the three dimensional display capability of the computer-implemented modelling system supports the placement of microwave systems;

Figure 7 is a flow chart illustrating the automated frequency assignment planning performed by the computer-implemented modelling system;

Figure 8 is a flow chart illustrating the management of the frequency assignment plans performed by the computer-implemented modelling system;

Figure 9 is a flow chart illustrating the automated cell location planning performed by the computer-implemented modelling system; and

Figure 10 is a flow chart illustrating the measurement integration performed by the computer-implemented modelling system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following Detailed Description of the Preferred Embodiment, reference is made to the accompanying Drawings which form a part hereof, and in which is shown by way of illustration embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized, and changes may be made to both the process and the structure without departing from the scope of the present invention.

GENERAL DESCRIPTION

The preferred embodiment of the present invention described herein is a computer-implemented modelling system for the design of wireless communications systems. The computer-implemented modelling system has a comprehensive set of software tools specifically developed for the design, development and management cellular telephone networks. Generally, the computer-implemented modelling system comprises means for creating, storing, retrieving, editing, and calculating system specifications in an electronic data format, including means for calculating and displaying predicted coverage of signal strength in a system service area. Preferably, the computer-implemented modelling system is derived from models disclosed in W.C.Y. Lee, <u>Mobile Cellular Telecommunications Systems</u>, McGraw-Hill Book Company, 1989, incorporated by reference herein.

However, more specific features are also provided in the present invention. For example, the present invention provides computer-implemented means for determining how to plan frequency assignments for cell sites. Automated frequency assignment planning allows the engineer to optimize the assignment of frequencies to cell sites within the cellular telephone network.

The present invention also provides computer-implemented means for determining how to increase the capacity of cell sites, how to split cell sites to support additional growth, and how to optimize placement of cell sites. Such automated cell location planning facilitates network optimization by the engineer.

In addition, the present invention provides computer-implemented means for using digital satellite terrain data, as well as three dimensional viewing of the terrain data. Satellite data is generally more accurate than traditional sources of topographical data. Three dimensional viewing of the terrain allows the engineer to make design decisions dependant upon the viewed topology of a desired service area.

Further, the present invention provides computer-implemented means for measurement integration to refine the accuracy of the modelling system. Measurement integration allows the engineer to adjust the predicted data based on measured data collected from field sites.

The system disclosed in the present application was conceived as an integrated solution to the problem of designing wireless communications systems. Of course, one skilled in the art will appreciate that the invention is not limited to cellular telephone networks, but may be used with any wireless communications systems. Using the present invention, the development time and expense associated with the design, development, and maintenance of wireless communications system can be reduced.

OVERVIEW

Figure 1 is a diagram depicting the hardware architecture of a computer-implemented modelling system for cellular telephone networks, in accordance with the principles of the present invention, including a workstation 10 and a relational database engine 12 for data storage and access. The engineer has the ability to specify user constants 14 for the modelling process. The results of the modelling process can be displayed on a graphic display monitor 16 controlled by graphic drivers 18. Plots and printouts of the results of the modelling process can be downloaded from the workstation 10 to printers and plotters 20.

The database 12 comprises a number of different types of information for the modelling process, including FAA and airport information 22, terrain data 24, geomorphic data 26, cell site parameters 28, frequency plans 30, FCC information 32, Carey data 34, overlays 36 of streets or other information, and demographic data 38. The FAA and airport information 22 is either fed into the database 12 automatically or input by the engineer manually. The digitized terrain elevation data 24 and the geomorphic data 26 are created from satellite photographs. The demographic data 38 is typically purchased from vendors for entry into the database 12 or entered manually by the engineer. Cell site parameters 28 and frequency plans 30 are typically generated and collected by the engineer for entry into the database 12. The FCC information 32 is generated by the system and stored for future reference. Carey data 34 is also generated by the system and stored for future reference. Overlays 36 of streets are typically purchased or digitized.

Those skilled in the art will readily recognize that any combination of workstations 10, database engine 12, graphic display monitor 16, graphics drivers 18, plotter/printer 20 and databases 22-38 could be substituted for the configuration shown.

Figure 2 is a diagram depicting the preferred components of the computer-implemented modelling system 40 in accordance with the present invention. A terrain formatting process 42 receives satellite geographical topology data 44 in order to create digital terrain data that is sent to the predictive modelling system 40. The engineer can set the desired coordinate boundaries 46 for the predictive modelling system 40 in order to establish the physical limitations to the predictions.

Mathematical models 48 are used by the modelling system 40 to perform numerous calculations for automatically planning frequency assignments, automatically determining predicted signal coverage, and automatically planning cell site capacity. Further, the mathematical models 48 used by the modelling system 40 to automatically plan cell site capacity includes mathematical models for determining how to increase capacity at cell sites, determining how to split the cells, and determining the optimum placement of cell sites. Preferably, the models conform to those disclosed in W.C.Y. Lee, Mobile Cellular Telecommunications Systems, McGraw-Hill Book Company, 1989, incorporated by reference herein, although other models could be used as well.

The calculations required by the mathematical models require many variables which are supplied by the different databases 50. Once the calculations are completed, the data is stored in the database 50 for later retrieval and use. Additionally, system parameters 52, such as grid resolution, are entered by the engineer and stored for future reference.

Figure 3 illustrates the logical hierarchy of some of the other features of the modelling system 40. Digitized satellite data 54 is entered into the modelling system 40 to provide more accurate topological representations of a service area, so that the engineer can make more accurate design decisions. Three dimensional viewing of the terrain 56 is provided to minimize the amount of field

work necessary to design the network. Automated frequency assignment planning 58 allows the engineer to set the rules the modelling system 40 uses to assign frequencies among cell sites. Automated cell site planning 60 facilitates network optimization by determining the optimum placement of cell sites, determining how to increase the capacity of cell sites, and determining how to split cell sites to support additional growth. Measurement integration 62 allows the engineer to adjust the modelling system 40 based on measured data collected in the field sites.

DIGITAL SATELLITE TERRAIN DATA

Figure 4 is a flow chart illustrating the entry and verification of the digital satellite data into the modelling system 40. Typically, satellite data has a higher resolution than data purchased from the U.S. Geological Survey or the U.S. Defense Map Agency. Further, it is considered to be more accurate.

Block 64 represents the review of the satellite photographs prior to loading them into the modelling system 40. Block 66 represents a decision point where the engineer can decide whether there is excess cloud cover in the photographs. Block 68 is performed when there is excess cloud cover and new satellite photographs are required. When the satellite photographs are suitable, block 70 represents the terrain formatting process 42 converting the satellite photographs into digital terrain data for use by the modelling system 40, wherein the digital terrain data provides more accurate topological representations of a service area, so that the engineer can make more accurate design decisions. Such terrain data includes a terrain elevation value, or above mean sea level (AMSL) number, for each latitude and longitude point therein. Block 72 represents the plotting and display of the terrain data on the printer/plotter 20 and the graphics display monitor 16 for the engineer. Block 74

represents a decision point where the engineer can decide to override the values of the terrain data, preferably to specify more accurate values. Block 76 represents the entry of an override AMSL value by the engineer. Block 78 represents the loading of the terrain data into the database 50 for further use by the modelling system 40.

THREE DIMENSIONAL VIEWING OF TERRAIN

A. Three Dimensional Terrain View

Figure 5 is a flow chart illustrating the three dimensional display capability of the computer-implemented modelling system 40. The function of the three dimensional displays is primarily to eliminate the need for engineers to perform field work, because the three dimensional displays are a reasonable similarity to the real terrain. Thus, using the modelling system 40, the engineer can determine whether features of the terrain block line-of-sight transmissions from cell sites.

Block 80 represents the selection of a utilities menu from which the three dimensional terrain view is displayed on a graphics display monitor 16. Block 82 represents the selection of a cell site or input coordinates by the engineer for the terrain they would like to see. Block 84 represents the modification of color thresholds by the engineer to facilitate ease of operation, for example, by using color to differentiate between various terrain or elevation features. Block 86 represents the function wherein the terrain field can be zoomed in and out, as well as panned and rotated, thereby providing the engineer with a complete overview of the service area. Block 88 is a decision block wherein the engineer can decide whether to plot out the screen image on a plotter 20. Block 90 performs the plotting function. Block 92 represents the modelling system's 40 ability to overlay geomorphic elements, including transmitter towers, road networks, etc., on the terrain view as well as the ability to overlay signal propagation predictions on the terrain

view. Further, block 92 represents the ability of the engineer to point at any spot on the three dimensional terrain view displayed on the graphics display monitor 16 and have the modelling system 40 return the latitude and longitude values as well as the elevation value stored for the selected point.

B. Microwave Placement

Figure 6 is a flow chart illustrating how the three dimensional display capability of the computer-implemented modelling system 40 supports the placement of microwave systems. The three dimensional terrain view displayed on a graphics display monitor 16 has special application to microwave placement, because of the need for line-of-sight transmissions between microwave sites. The three dimensional terrain view shows the engineer the terrain between two potential microwave sites. These displays also show the engineer parameters regarding the microwave path.

Block 94 represents the engineer choosing a microwave line-of-site path between two points (spot and return location) either from the database 50 or by entering locations manually into the modelling system 40. Block 96 represents the modelling system 40 graphically illustrating the terrain on the chosen path. The engineer is also able to view important parameters related to the microwave sites on the graphic display 16. Block 98 is a decision block wherein the modelling system 40 enables the engineer to determine whether the path is blocked or not. Block 100 represents the plotting of this display by the modelling system 40 at the engineer's request.

AUTOMATED FREQUENCY ASSIGNMENT PLANNING

A. Frequency Assignment Planning.

Figure 7 is a flow chart illustrating the automated frequency assignment planning performed by the computer-implemented modelling system 40. The function of frequency assignment planning is to divide the total number of available channels, i.e., frequencies, in the network into subsets which can be assigned to each cell site. Further, a certain amount of channel sharing can exist in the network, typically so long as adjacent cell sites do not attempt to share the same channel, which would cause interference. Additionally, frequency assignment planning must also take into account any sectorization in a cell site, wherein the sector angles of the various sectors typically determine the number of channels that can be assigned in the sectors without increasing neighboring channel interference. Thus, the modelling system 40 allows the engineer to determine frequency assignments in a manner providing the most optimal solution for the network.

Block 104 represents the display of a list of existing frequency assignment plans on the graphics display monitor 16. Block 106 is a decision block wherein the engineer either selects and retrieves an existing plan or initiates a new plan; block 108 represents the retrieval of the existing plan. Blocks 110-116 represent the defining by the engineer of various criteria for the frequency assignment planning to be performed by the modelling system 40, including blocking probabilities 110, the percentage change allowed to the network 112, the percentage of interference allowed in the network 114, and the amount of time the modelling system 40 can take in determining optimal solutions 116. Once the criteria are defined, block 118 represents the modelling system 40 making the determination which of one or more possible frequency assignment plans provides an optimal solution. Preferably, the modelling system 40 uses the frequency assignment planning techniques disclosed in W.C.Y. Lee, Mobile Cellular Telecommunications Systems, McGraw-Hill

Book Company, 1989, incorporated by reference herein. Block 120 represents the modelling system 40 displaying the solutions for the engineer according to their degree of optimality, i.e., from those which are most optimal to those which are least optimal, according to the defined criteria.

B. Management of Frequency Assignment Plans.

Figure 8 is a flow chart illustrating the management of the frequency assignment plans performed by the computer-implemented modelling system 40. Block 122 represents the selection of a database menu for managing the frequency assignment plans. Block 124 represents the listing of current frequency assignment plans from the database 50. Block 126 represents the functions of adding, modifying or deleting frequency assignment plans from the database 50. Block 128 represents the modelling system 40 capability of displaying and reporting the frequency assignments by sector, including the capability of plotting such assignments on the plotter 20.

AUTOMATED CELL SITE PLANNING

Figure 9 is a flow chart illustrating the automated cell location planning performed by the computer-implemented modelling system 40. The function of cell site planning is to increase the traffic capacity of a cell site as the demand for additional capacity increases. Further, the repercussions of increased capacity in one cell site on surrounding cell sites must be considered, to minimize or eliminate any interference that the increased capacity would cause. Additionally, such planning must take into account the demographics of the service area and trending information so that the increase in capacity will satisfy growth expectations for some predetermined period of time, thereby eliminating the need to perform costly upgrades again sooner than expected. Thus, using the modelling system 40, the engineer can determine capacity

upgrades in a manner providing the most optimal solution for the network.

Block 130 represents the loading of a database 50 of demographics data into the modelling system 40. Block 132 represents the loading of a database 50 of cell site usage and trending data into the modelling system 40. Block 134 represents the engineer selecting and retrieving a frequency assignment plan that reflects the current network design. Block 136 represents the modelling system 40 determining which of one or more cell sites require additional capacity as well as an optimal solution for providing that additional capacity. Preferably, the modelling system 40 uses the cell site planning techniques disclosed in W.C.Y. Lee, Mobile Cellular Telecommunications Systems, McGraw-Hill Book Company, 1989, incorporated by reference herein. Generally, these solutions will take one of three forms: (1) splitting the cell site into two cell sites; (2) adding new sectors to an existing cell site; or (3) adding more capacity at the existing cell site. Block 138 is a decision block wherein control is transferred to blocks 140, 142, or 146, depending on how the additional capacity is handled.

Block 140 represents the addition of more capacity to the existing cell site, i.e., the addition of more channels to the cell site. This typically requires an investment in additional transceivers and other equipment at the cell site.

Block 142 represents the addition of new sectors to the existing cell site, which typically requires the addition of directional antennae to the cell site. Block 144 represents the updating of parameters for all sectors in the cell site.

Block 146 represents the splitting of the cell site into two cell sites. Block 148 represents the determination of the boundaries for the old and new cell sites, which typically occurs without moving the transmitter for the old cell site. Block 150 represents

the determination of the optimal transmitter location for the new cell site. Block 152 represents the updating of parameters for the old and new cell sites.

In all of the above alternatives, the modelling system 40 preferably displays one or more solutions according to their degree of optimality, i.e., from those which are most optimal to those which are least optimal, according to the defined criteria.

MEASUREMENT INTEGRATION

Figure 10 is a flow chart illustrating the measurement integration performed by the computer-implemented modelling system 40. The function of measurement integration is to increase the accuracy of the modelling system 40 as more "real world" data is collected. Preferably, an iterative process, measurement integration ensures that the modelling system 40 provides optimal solutions to the network design problems.

Block 154 represents the collection of a database 50 of measured data for loading into he modelling system 40. Typically, this measured data is derived using testing which "drive" the cellular telephone network. Additionally, an engineer may take field measurements and collect standard network performance, billing and alarming information for inclusion into the database 50. Block 156 represents the conversion of the collected measured data into a format suitable for use by the modelling system 40. Block 158 represents the modelling system 40 graphically displaying or plotting the data. Block 160 represents the modelling system 40 comparing calculated and stored predicted data against the measured data. Block 162 represents the modelling system 40 determining the statistical adjustments to make to the predicted data so that it more closely matches the measured data in terms of results. Block 164 represents the modelling system 40 reporting the statistical adjustments to the engineer and block 166 represents the modelling system 40 storing the

statistical adjustments.

CONCLUSION

This concludes the description of the preferred embodiment of the invention. In summary, the present invention discloses a computer-implemented modelling system having a comprehensive set of software tools specifically developed for the design, development and management of wireless communications systems. Generally, the computer-implemented modelling system comprises means for creating, storing, retrieving, editing, and calculating system specifications in an electronic data format, including means for calculating and displaying predicted coverage of signal strength in a system service area. Preferably, the computer-implemented modelling system is derived from models disclosed in W.C.Y. Lee, Mobile Cellular Telecommunications Systems, McGraw-Hill Book Company, 1989, incorporated by reference herein.

However, more specific features are also provided in the present invention. For example, the present invention provides computer-implemented means for determining how to plan frequency assignments for cell sites. Automated frequency assignment planning allows the engineer to optimize the assignment of frequencies to cell sites within the cellular telephone network.

The present invention also provides computer-implemented means for determining how to increase the capacity of cell sites, how to split cell sites to support additional growth, and how to determine the optimum placement of cell sites. Such automated cell location planning facilitates network optimization by the engineer.

In addition, the present invention provides computer-implemented means for using digital satellite terrain data, and three dimensional viewing of the terrain data. Satellite data is considered more accurate than other forms of terrain data. Three dimensional viewing of the terrain allows the engineer to make design decisions

dependant upon the viewed topology of a desired service area.

Further, the present invention provides computer-implemented means for measurement integration to refine the accuracy of the modelling system. Measurement integration allows the engineer to adjust the predicted data based on measured data collected in the field sites.

The system disclosed in the present application was conceived as an integrated solution to the problem of designing wireless communications systems. Of course, one skilled in the art will appreciate that the invention is not limited to cellular telephone networks, but may be used with any wireless communications systems. Using the present invention, the development time and expense associated with the design, development and management of wireless communications system can be reduced.

The foregoing description of the preferred embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not be this detailed description, but rather by the claims appended hereto.

WHAT IS CLAIMED IS:

1. A computer-implemented modelling system for wireless communications systems, comprising:

(a) one or more computers;

(b) data storage means, executed by one or more of the computers, for the storage and retrieval of information related to one or more wireless communications systems; and

(c) design means, executed by one or more of the computers and coupled for access to the data storage means, for creating, storing, retrieving, editing, and calculating network specifications in an electronic data format, including means for calculating and displaying predicted coverage of signal strength in a service area, the design means further comprising means for determining how to plan frequency assignments for cell sites, thereby allowing a user to optimize the assignment of frequencies to cell sites within the wireless communications system.

2. The invention as set forth in claim 1 above, wherein the means for determining comprises means for defining optimal solutions to the assignment of frequencies according to blocking probabilities criteria.

3. The invention as set forth in claim 1 above, wherein the means for determining comprises means for defining optimal solutions to the assignment of frequencies according to a percentage change to the network.

4. The invention as set forth in claim 1 above, wherein the means for determining comprises means for defining optimal solutions to the assignment of frequencies according to a percentage of interference in the network.

5. The invention as set forth in claim 1 above, wherein the means for determining comprises means for defining optimal solutions to the assignment of frequencies according to an amount of time to take in determining the optimal solutions.

6. The invention as set forth in claim 1 above, wherein the means for determining comprises means for displaying a plurality of solutions to the assignment of frequencies, wherein the solutions are displayed according to their degree of optimality.

7. A computer-implemented modelling system for wireless communications systems, comprising:

(a) one or more computers;

(b) data storage means, executed by one or more of the computers, for the storage and retrieval of information related to one or more wireless communications systems; and

(c) design means, executed by one or more of the computers and coupled for access to the data storage means, for creating, storing, retrieving, editing, and calculating network specifications in an electronic data format, including means for calculating and displaying predicted coverage of signal strength in a service area, the design means further comprising means for adding additional capacity to the network, including means for determining how to increase the capacity of cell sites, how to split cell sites to support additional growth, and how to determine the optimum placement of cell sites, thereby facilitating network optimization.

8. The invention as set forth in claim 7 above, wherein the means for adding further comprises means for defining optimal solutions according to demographics data for the service area.

9. The invention as set forth in claim 7 above, wherein the means for adding further comprises means for defining optimal solutions according to cell site usage and trending data for the service area.

10. The invention as set forth in claim 7 above, wherein the means for adding further comprises means for defining optimal solutions according to frequency assignments for the network.

11. The invention as set forth in claim 7 above, wherein the means for adding further comprises means for displaying a plurality of solutions, wherein the solutions are displayed according to their degree of optimality.

12. A computer-implemented modelling system for wireless communications systems, comprising:

(a) one or more computers;

(b) data storage means, executed by one or more of the computers, for the storage and retrieval of information related to one or more wireless communications systems; and

(c) design means, executed by one or more of the computers and coupled for access to the data storage means, for creating, storing, retrieving, editing, and calculating network specifications in an electronic data format, including means for calculating and displaying predicted coverage of signal strength in a service area, the design means further comprising means for using digital satellite terrain data to display the topology of the service area.

13. The invention as set forth in claim 12 above, wherein the terrain data comprises terrain elevation values.

14. The invention as set forth in claim 12 above, wherein the terrain data comprises above mean sea level (AMSL) numbers for each latitude and longitude point therein.

15. The invention as set forth in claim 12 above, wherein the design means further means for overriding the terrain data.

16. A computer-implemented modelling system for wireless communications systems, comprising:

(a) one or more computers;

(b) data storage means, executed by one or more of the computers, for the storage and retrieval of information related to one or more wireless communications systems; and

(c) design means, executed by one or more of the computers and coupled for access to the data storage means, for creating, storing, retrieving, editing, and calculating network specifications in an electronic data format, including means for calculating and displaying predicted coverage of signal strength in a service area, the design means further comprising means for displaying three dimensional terrain data to illustrate the topology of the service area.

17. The invention as set forth in claim 16 above, wherein the means for displaying comprises means for illustrating whether features of the terrain block line-of-sight transmissions from cell sites.

18. The invention as set forth in claim 16 above, wherein the means for displaying comprises means for displaying terrain selected from coordinates entered by the user.

19. The invention as set forth in claim 16 above, wherein the means for displaying comprises means for displaying terrain selected from a cell site identifier entered by the user.

20. The invention as set forth in claim 16 above, wherein the means for displaying comprises means for displaying the three dimensional terrain data using color to differentiate between various features thereof.

21. The invention as set forth in claim 16 above, wherein the means for displaying comprises means for overlaying geomorphic features on the three dimensional terrain data.

22. The invention as set forth in claim 16 above, wherein the means for displaying comprises means for overlaying signal coverage predictions on the three dimensional terrain data.

23. The invention as set forth in claim 16 above, wherein the means for displaying comprises means for reporting latitude and longitude values for selected points of the displayed three dimensional terrain data.

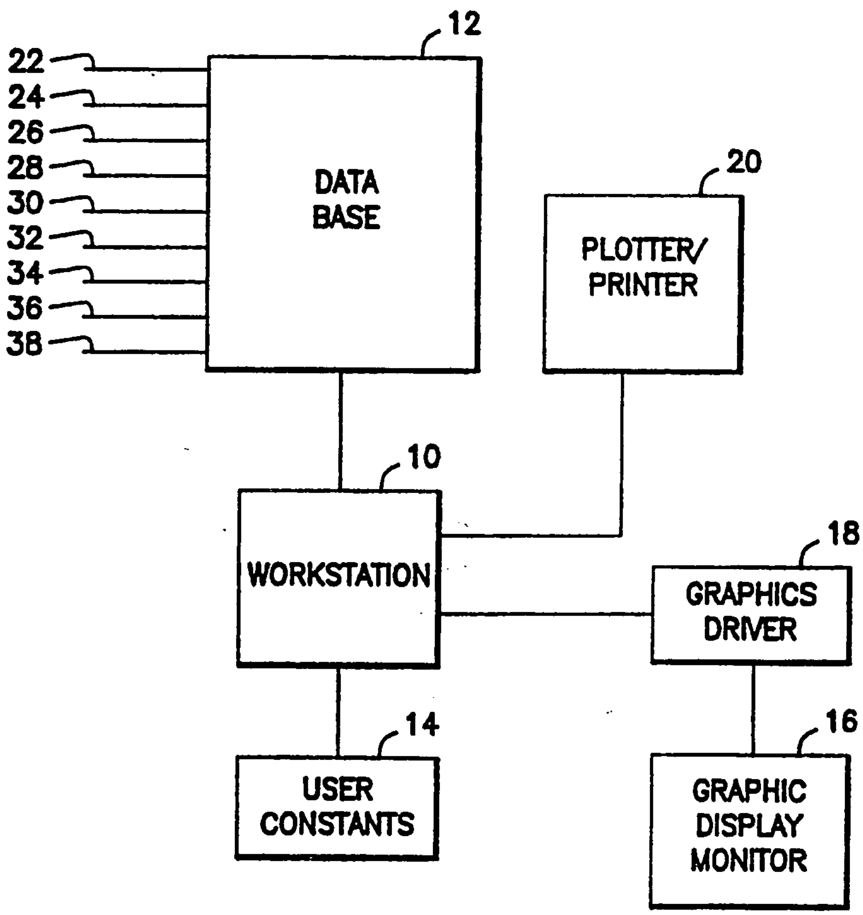
24. A computer-implemented modelling system for wireless communications systems, comprising:

(a) one or more computers;

(b) data storage means, executed by one or more of the computers, for the storage and retrieval of information related to one or more wireless communications systems; and

(c) design means, executed by one or more of the computers and coupled for access to the data storage means, for creating, storing, retrieving, editing, and calculating network specifications in an electronic data format, including means for calculating and displaying

predicted coverage of signal strength in a service area, the design means further comprising means for measurement integration to refine the accuracy of the modelling system, wherein the means for measurement integration comprises means for adjusting the means for calculating based on measured data collected from the network.


12
22
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DATA BASE
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PLOTTER/ PRINTER
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WORKSTATION
18
GRAPHICS DRIVER
14
USER CONSTANTS
16
GRAPHIC DISPLAY MONITOR

FIG. 1

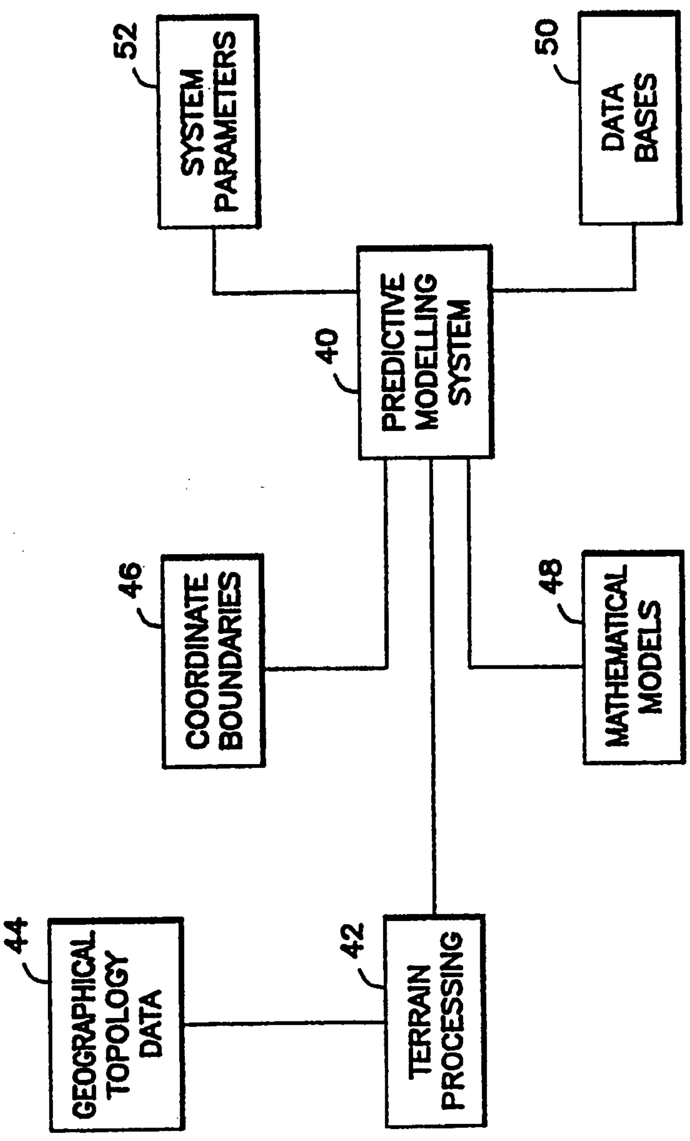

52
SYSTEM PARAMETERS
50
DATA BASES
40
PREDICTIVE MODELLING SYSTEM
46
COORDINATE BOUNDARIES
48
MATHEMATICAL MODELS
44
GEOGRAPHICAL TOPOLOGY DATA
42
TERRAIN PROCESSING

FIG. 2

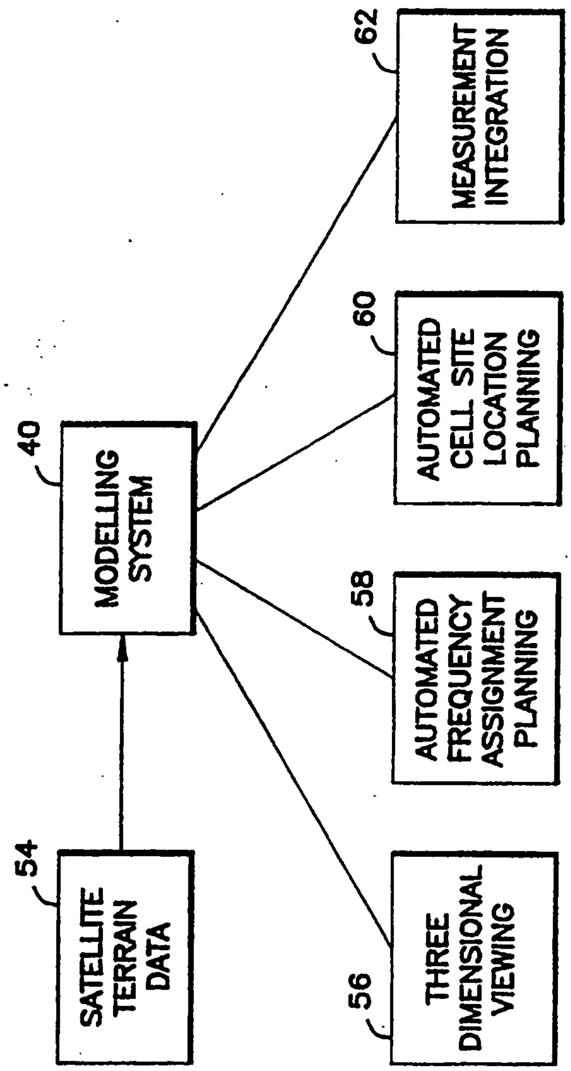

40
MODELLING SYSTEM
54
SATELLITE TERRAIN DATA
56
THREE DIMENSIONAL VIEWING
58
AUTOMATED FREQUENCY ASSIGNMENT PLANNING
60
AUTOMATED CELL SITE LOCATION PLANNING
62
MEASUREMENT INTEGRATION

FIG. 3

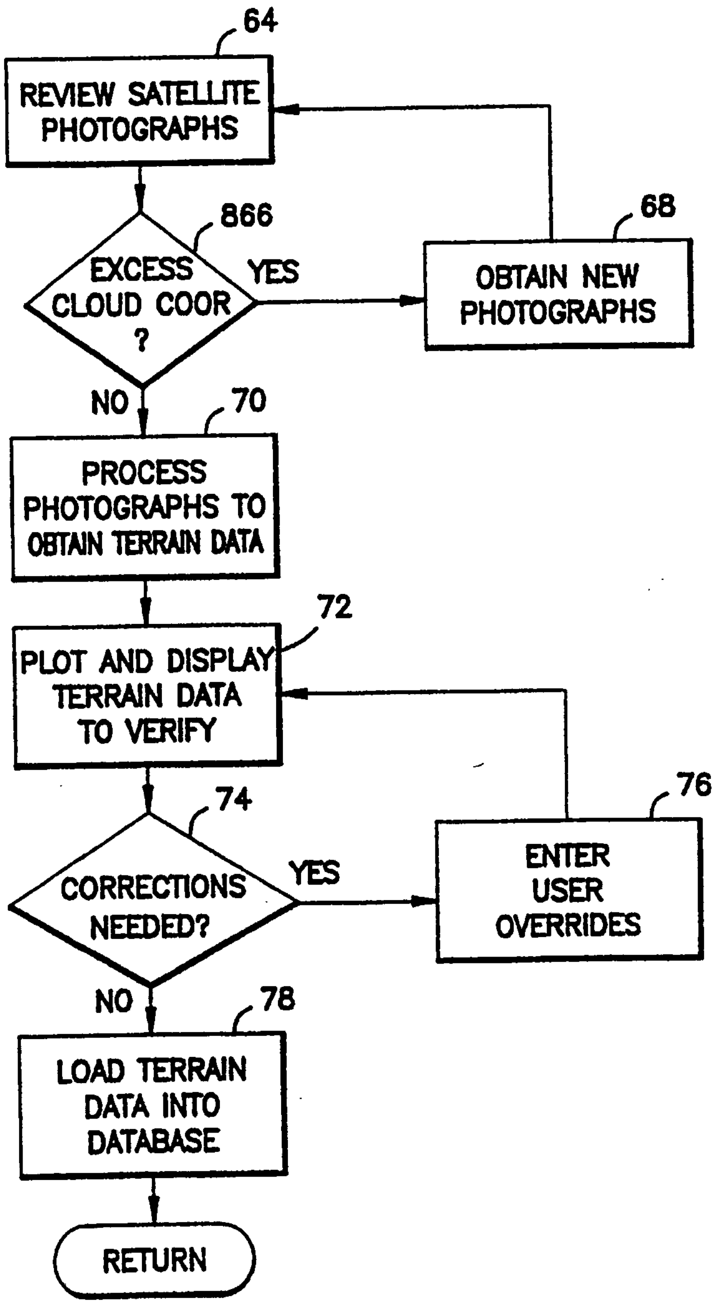

64
REVIEW SATELLITE PHOTOGRAPHS
866
EXCESS CLOUD COOR ?
YES
68
OBTAIN NEW PHOTOGRAPHS
NO
70
PROCESS PHOTOGRAPHS TO OBTAIN TERRAIN DATA
72
PLOT AND DISPLAY TERRAIN DATA TO VERIFY
74
CORRECTIONS NEEDED?
YES
76
ENTER USER OVERRIDES
NO
78
LOAD TERRAIN DATA INTO DATABASE
RETURN

FIG. 4

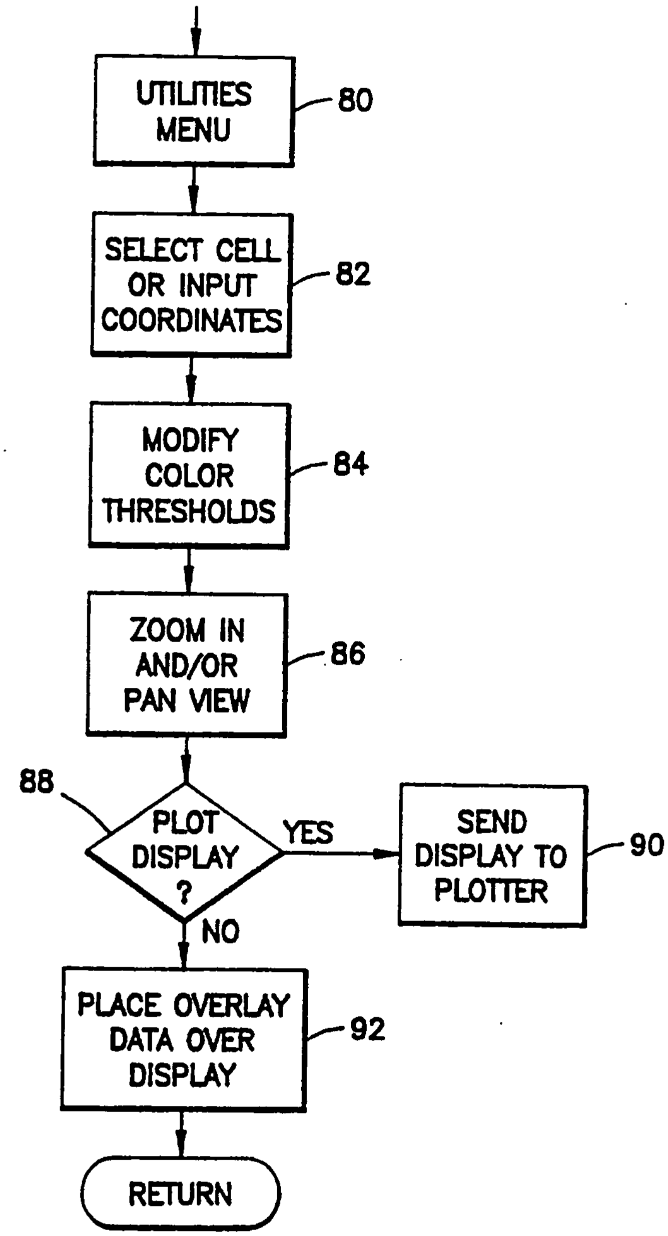

UTILITIES MENU
80
SELECT CELL OR INPUT COORDINATES
82
MODIFY COLOR THRESHOLDS
84
ZOOM IN AND/OR PAN VIEW
86
88
PLOT DISPLAY ?
YES
SEND DISPLAY TO PLOTTER
90
NO
PLACE OVERLAY DATA OVER DISPLAY
92
RETURN

FIG. 5

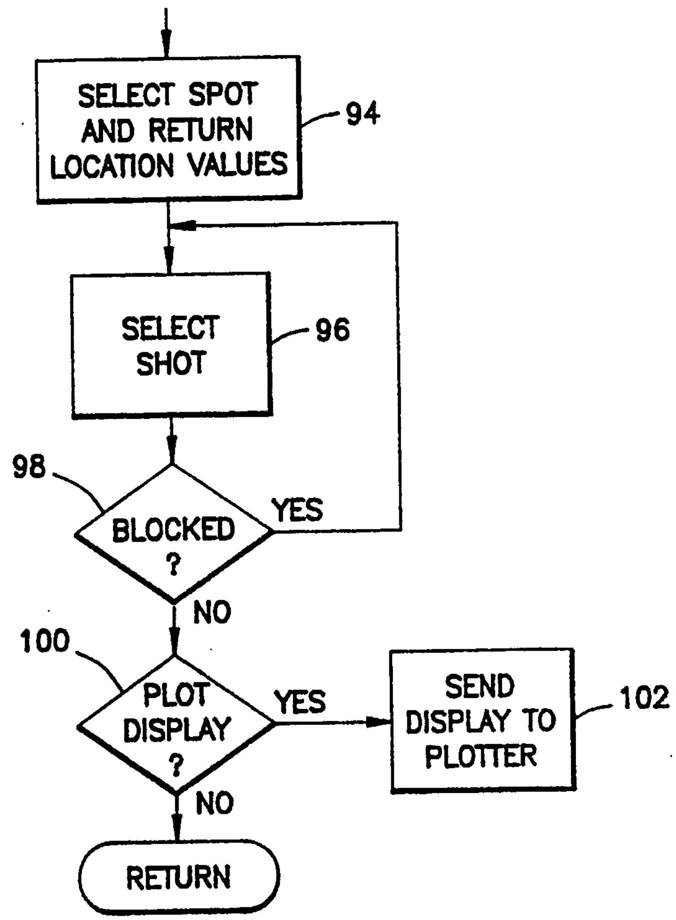

SELECT SPOT AND RETURN LOCATION VALUES
94
SELECT SHOT
96
98
BLOCKED ?
YES
NO
100
PLOT DISPLAY ?
YES
SEND DISPLAY TO PLOTTER
102
NO
RETURN

FIG. 6

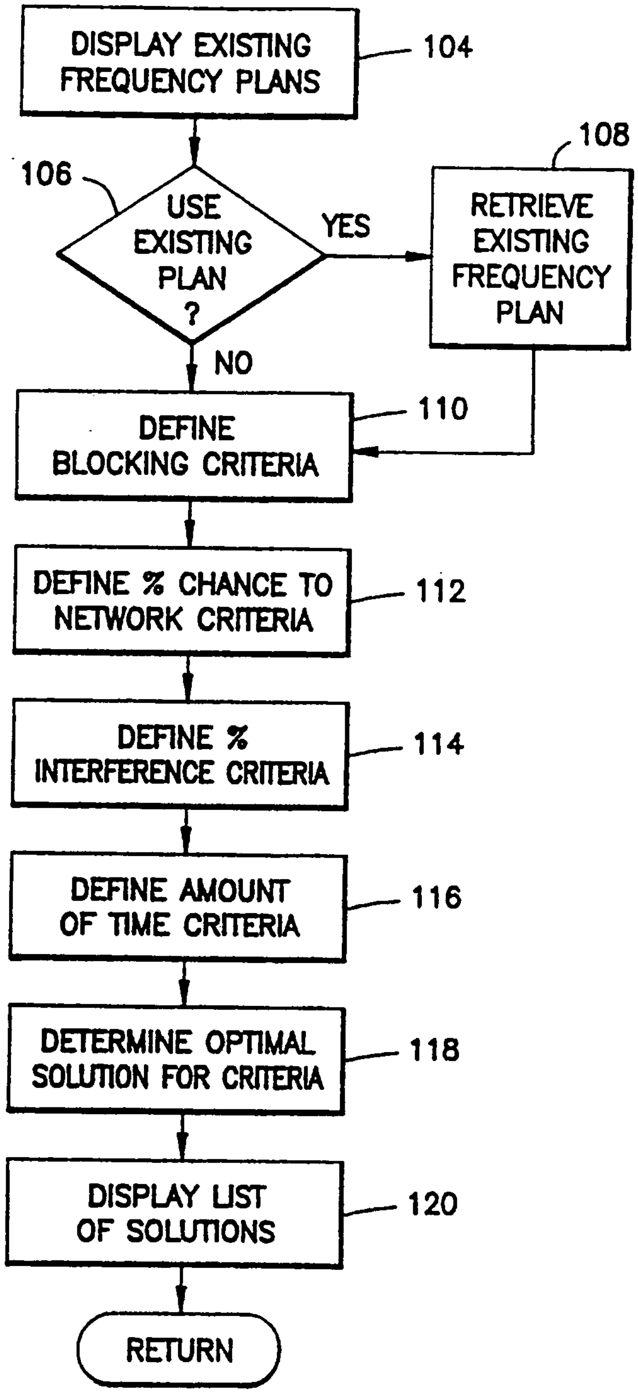

DISPLAY EXISTING FREQUENCY PLANS
104
106
USE EXISTING PLAN ?
YES
108
RETRIEVE EXISTING FREQUENCY PLAN
NO
DEFINE BLOCKING CRITERIA
110
DEFINE % CHANCE TO NETWORK CRITERIA
112
DEFINE % INTERFERENCE CRITERIA
114
DEFINE AMOUNT OF TIME CRITERIA
116
DETERMINE OPTIMAL SOLUTION FOR CRITERIA
118
DISPLAY LIST OF SOLUTIONS
120
RETURN

FIG. 7

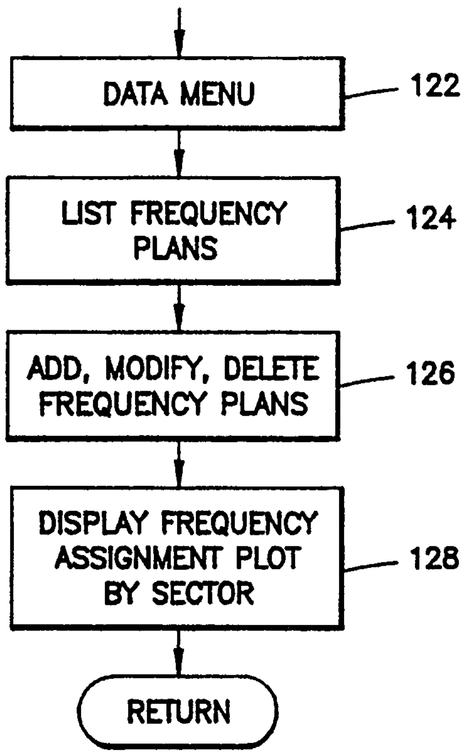
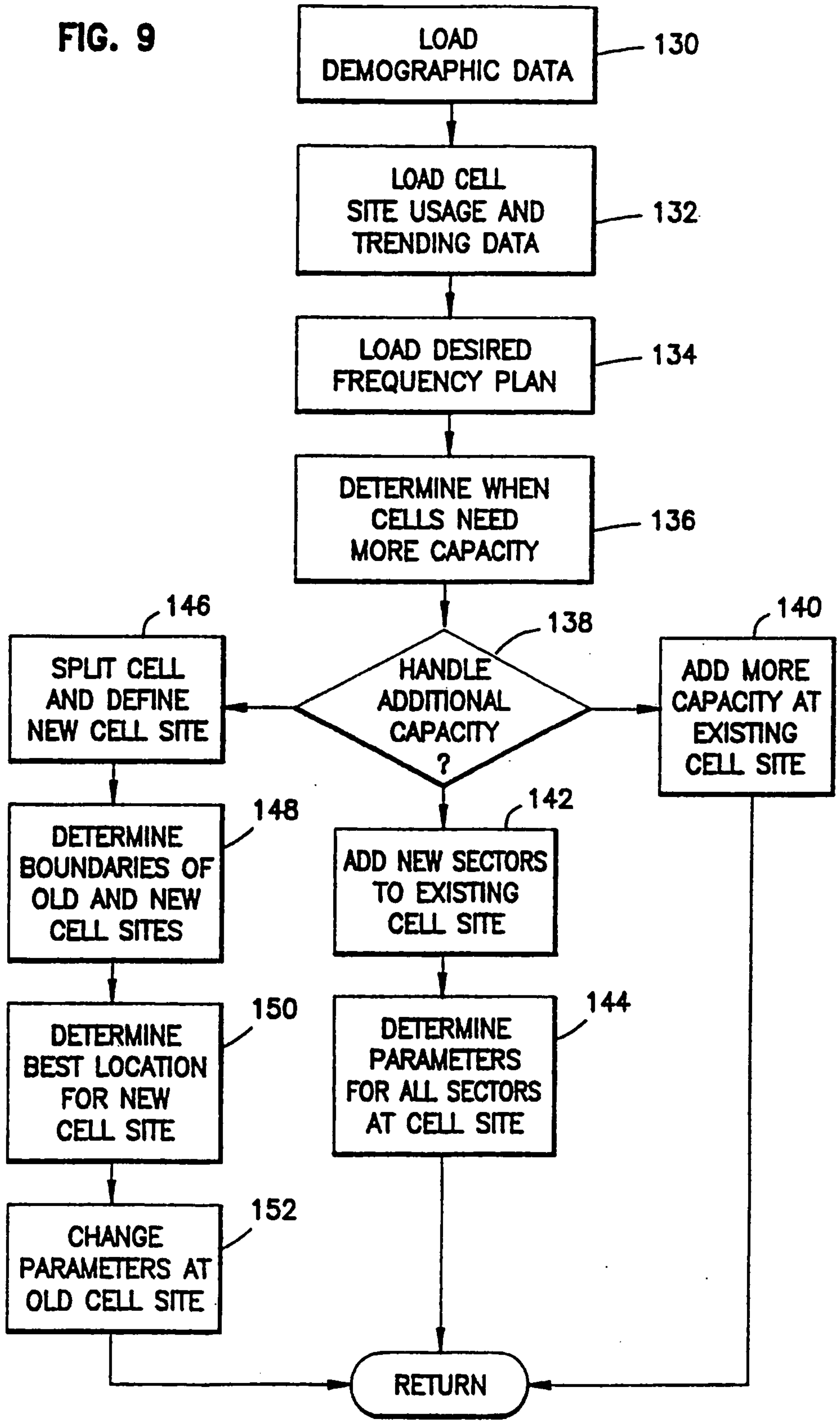

DATA MENU
122
LIST FREQUENCY PLANS
124
ADD, MODIFY, DELETE FREQUENCY PLANS
126
DISPLAY FREQUENCY ASSIGNMENT PLOT BY SECTOR
128
RETURN

FIG. 8

FIG. 9


LOAD DEMOGRAPHIC DATA
130
LOAD CELL SITE USAGE AND TRENDING DATA
132
LOAD DESIRED FREQUENCY PLAN
134
DETERMINE WHEN CELLS NEED MORE CAPACITY
136
HANDLE ADDITIONAL CAPACITY ?
138
SPLIT CELL AND DEFINE NEW CELL SITE
146
ADD MORE CAPACITY AT EXISTING CELL SITE
140
DETERMINE BOUNDARIES OF OLD AND NEW CELL SITES
148
ADD NEW SECTORS TO EXISTING CELL SITE
142
DETERMINE BEST LOCATION FOR NEW CELL SITE
150
DETERMINE PARAMETERS FOR ALL SECTORS AT CELL SITE
144
CHANGE PARAMETERS AT OLD CELL SITE
152
RETURN

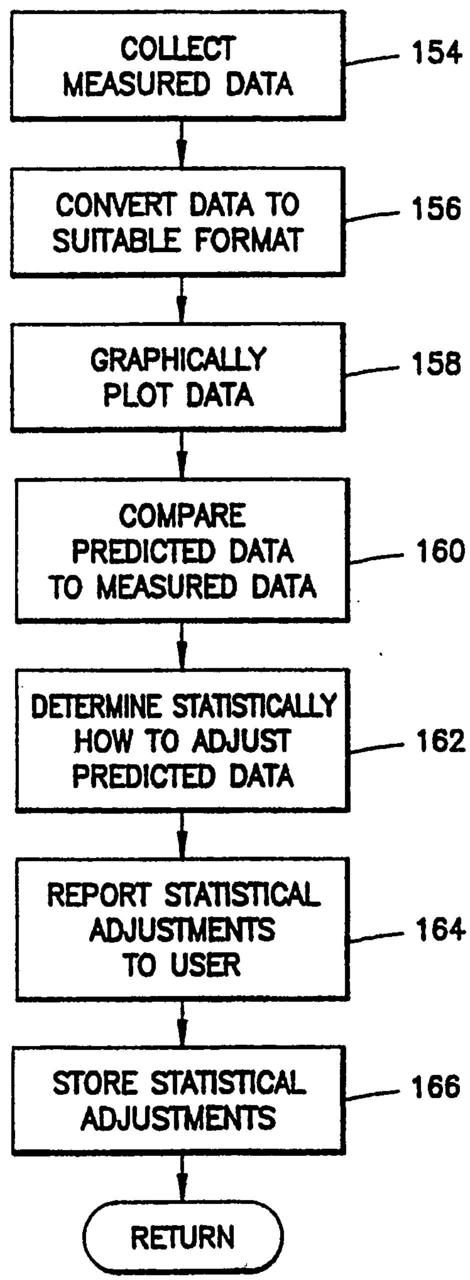

COLLECT MEASURED DATA
154
CONVERT DATA TO SUITABLE FORMAT
156
GRAPHICALLY PLOT DATA
158
COMPARE PREDICTED DATA TO MEASURED DATA
160
DETERMINE STATISTICALLY HOW TO ADJUST PREDICTED DATA
162
REPORT STATISTICAL ADJUSTMENTS TO USER
164
STORE STATISTICAL ADJUSTMENTS
166
RETURN

FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 93/05112

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H04B7/26

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H04Q

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	40TH IEEE VEHICULAR TECHNOLOGY CONFERENCE, ORLANDO 6 May 1990, NEW-YORK (US) pages 378 - 383 D.M. LARSEN ET AL 'MSFRM - A Prediction Tool For Radio System Design' see page 379, left column, line 7 - page 383	1-4,7,8, 10,12-24
X	6TH MEDITERRANEAN ELECTROTECHNICAL CONFERENCE, LJUBLJANA vol. 1, 22 May 1992, NEW-YORK (US) pages 643 - 646 H. BÜHLER ET AL 'PICAM: A PC Based Cellular Network Planning Software Package' see the whole document	1,4,5,7, 8,12-14, 16-18, 20-24

-/--

° Special categories of cited documents :[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20 SEPTEMBER 1993	29.09.93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	GERLING J.C.J.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	39TH IEEE VEHICULAR TECHNOLOGY CONFERENCE, SAN-FRANCISCO vol. II, 1 May 1989, NEW-YORK (US) pages 823 - 831 A.H. ABOULGASEM ET AL 'COMPUTER-AIDED DESIGN OF SPECIAL PURPOSE SYSTEMS' see page 823, paragraph 2 - page 824, paragraph 3 see page 826, paragraph 7 - page 827, paragraph 10 see page 829; tables 1-4 see figures 2,4,8 ---	1-4,6,7, 9-14, 16-18,23
X	PHILIPS TELECOMMUNICATION REVIEW vol. 49, no. 3, September 1991, HILVERSUM NL pages 18 - 22 R. BECK ET AL 'GRAND - A Program System for Radio Network Planning' see page 18, left column, line 14 - right column, line 6 see page 18, right column, paragraph 2 - page 21, left column, paragraph 4 -----	1-4,24